Yoshiko YANAGIDA

Bunka Women's University, JAPAN

Analyzing the Human Figure using 3D Measurements to Design Clothing for the Elderly - Focus on Neck and Shoulders

1. Introduction

In recent years, consumer sentiment has spread into areas such as quality, functions, environment and health. In response to the rapid transition to an aging society, in particular, making products and environmental rules that take elderly people into account has become an important element of policy. Until now, the apparel industry and apparel researchers have mainly been concerned with fashion proposals and clothing design aimed at young people. Given the present climate, however, they have started to realize the importance of research on elderly people, with a view to designing and supplying better clothes for elderly people. With specific reference to the clothing sector, a "Guideline for designing of clothes in consideration of elderly people –Apparel– JIS S 0023" was established as a JIS standard in January 2002. (Japanese Industrial Standard Committee, 2002) But while it indicates guidelines in consideration of clothes for elderly people, it makes little mention of specific matters.

Nevertheless, it stresses the importance of research on clothes design for elderly people who differ from young people both physiologically and psychologically.

In research to date, the author has already studied the creation of a system for automatic setting of measurement points for clothes design based mainly on human body shapes aimed at young women. (Yanagida, 2006: 1-10) The purpose of this paper, therefore, is to focus on measurement points of elderly people in the neck and shoulders, in which there is significant divergence between individuals, and to analyze characteristics of the neck and shoulders of elderly people using data from measurement point coordinates and shape patterns (e.g. lateral cross section shapes) formed by 3-D measurement. In this way, the aim was to discover morphological differences compared to young women. These would then be used as basic data for designing better fitting clothes for elderly people, with a view to enhancing and establishing clothing lifestyles for elderly people who will form a focus of consumer economic activity in future, bearing in mind the expected advance of the aging society.

2. The importance of research on clothes for elderly people

The total population of Japan as of October 1st, 2007, was 127.77 million, more or less on a par with the previous year. In contrast, the population of elderly people aged 65 or over reached a new record high of 27.46 million (compared to 26.60 million in the previous year). The ratio compared to the general population (aging ratio) also

increased to 21.5% (20.8% in the previous year), exceeding 21% for the first time. Moreover, of the elderly population, the population of those in the early elderly phase (65-74) was 14.76 million (men 6.94 million, women 7.82 million, gender ratio 88.7), accounting for 11.6% of the general population, while those in the late elderly phase (75 or over) numbered 12.70 million (men 4.77 million, women 7.94 million, gender ratio 60.0), accounting for 9.9% of the general population. (Cabinet Office, 2008) In response to this rapidly aging society, a “Guideline for designing of clothes in consideration of elderly people –Apparel– JIS S 0023” was established as a JIS standard in January 2002. (Japanese Industrial Standard Committee, 2002) This established guidelines for considering product design from various angles on the premise that elderly people should be able to live in greater comfort and safety in all aspects of their lives. In the context of clothing, the Guideline proposes better clothes for elderly people in the future, among others, based on actual questionnaire surveys of elderly people and their clothing requirements. In a survey of satisfaction with the shape and size of clothes (n=117), for example, about 70% of respondents expressed some dissatisfaction with clothes, “Dissatisfied” accounting for 25% and “Rather dissatisfied” for 45%. Besides this, many respondents expressed views such as “Clothes designed for elderly people are not attractive”, “There are too few fashion options for elderly people”, or “Fashionable clothes are aimed at young people, and the sizes don’t fit us”. The Guideline highlights the need to enumerate these specific problems and, at the same time, to solve them quickly.

Research aimed at designing better fitting clothes has often been carried out for young people; progress in this field is conspicuous, including research on clothes design tailored to the individual. In contrast, research on clothes design for elderly people is often based on the algorithm of young people, and mainly consists of amendments or alterations to fit the sizes and other characteristics of elderly people. In particular, body measurements of elderly people have frequently been carried out but the measurement data obtained are merely averaged out from basic dimensions such as bust, waist and hips. These are then used as data to develop mannequins for elderly people, or, frequently, as parameters for increasing or decreasing the sizes used for young people, such as data for amending pattern-making sizes. However, no attempt had been made to set anatomical characteristic points (landmarks) in human figure measurement that form the basis of clothes manufacture, or to grasp the correlations between these. Instead, the focus on elderly people's clothes design is based on simple pattern amendment and theory. As a result, clothes designed at present are not adequately suited to the wearers.

Measurement points are the most important element in analyzing body shape characteristics. Anatomical landmarks, i.e. human figure measurement points, are very important as datum points not only for measuring and classifying figure and shape, but also for creating the "templates" that are fundamental to clothes design,

and for body shape indicators in sites of education. Even in clothes design, use is made not only of conventional measurement points that are defined in conventional anthropology and human engineering (ergonomics), but also of several measurement points that are set using morphological landmarks based on the contours of the human figure, etc. The neck and shoulders, in particular, are important points of support for clothes and are very complex loci that include a combination of measurement points shared in common with definitions in ergonomics. For example, these measurement points use, as datum points, epiphysis (rounded ends of long bones), apophysis (bony protuberance), incisions and other features in the skeleton that can only be set by palpation. Also involved in these loci are measurement points based on protrusion points, concave points and other features that can be gleaned from the outer contours of the human figure. In the case of young people, the difference between individuals is relatively small if we exclude body shape changes due to either fatness or thinness (particularly the former). But in the case of elderly people, there is pronounced broadening of the range in both directions (i.e. both obesity and emaciation), as well as changes in skeleton and posture with increased age. This makes it difficult to adapt to this using pattern matching of standard human figure characteristics. As such, grasping the shape of the human figure graphically based on human figure measurement points and ascertaining characteristics of changes in figure and posture will help to provide important indicators for designing better fitting clothes for elderly people.

Today, improvement in QOL (Quality of Life) is sought in a variety of fields, and it is inevitable that strategies targeting the 30's DINKS bracket (Double Income No Kids) in the field of apparel will shift their focus to target groups dominated by the elderly age bracket. In an age when elderly people will represent the focus of consumption, the author feels that increasing the satisfaction of elderly people in their apparel will lead to an improvement in the quality of their lives as a whole, promote a stimulation of consumer lifestyles in society at large, and help to achieve an affluent social life.

3. Measurement of elderly people using 3-D measuring instruments

3-1. Outline of 3-D measuring instruments

This university has introduced three 3-D measuring instruments. For this research, the author used six one-dimensional distance measuring instruments consisting of a laser light source, CCD camera and rotating mirror. The subject to be measured would stand inside a polygonal pillar-shaped capsule, where the body surface would be scanned by laser light using 60° mirror rotation, the reflected light would be received by a CCD image sensor, and data would be obtained by trigonometrical calculation. When measuring non-static characteristics of the human figure, movement of the human figure cannot be completely prevented when attempting to maintain posture and accurate measurement is difficult. When measuring elderly people, in particular, the measurement time is known to have a pronounced effect on measurement

accuracy compared to when measuring young people. As instruments that are less susceptible to the impact of measurement time, a type of instrument that emits laser light in a slit shape, and a “lattice pattern projection method” 3-D measuring instrument that projects a lattice pattern onto the body surface for measurement have been introduced at this university. 3-D measuring instruments using the lattice pattern projection system can measure the whole of the subject body at once, and in a very short time. Also, since they can measure subjects that have complex surfaces as well as both light and dark areas they can measure subjects in a bright room without needing to turn off the lights. Moreover, since they use a data projector (white light) for projecting patterns they have the advantage of exerting little impact on the human figure. This makes them eminently suited to the measurement of elderly people for whom a number of special considerations have to be made when actually carrying out measurement. In this research lab, in fact, human figure measurement had been carried out for more than 300 elderly people using these 3-D measuring instruments up to the last fiscal year. The lab is now pursuing research with a view to acquiring data for more detailed shape analysis. However, even if progress is made in reducing measurement time by any of these instruments there has been a lack of continuous research such as software design for data interpolation accompanying data omissions when measuring the neck and shoulders. This measurement is extremely important in terms of measuring the complex shapes of the human figure, particularly in connection with clothes design, and requires a high precision of measurement in order to

ascertain shapes. Thus, the author decided to use 3-D measuring instruments with 6-directional irradiation even though the measurement time would be slightly longer. This was in view of the fact that extracting data from 6 directions would make it possible to reduce data omissions on the neck and shoulders of the human figure, and that a number of systems have been added or improved in clothes design based on the various research results of this university. (Miyoshi & Isozaki, 1992: 1-17) (Miyoshi & Kim, 1999: 61-69) (Miyoshi & Hirokawa, 2001: 37-46)

3-2. Garments worn and posture during measurement

As garments worn by the subjects, it was decided that they should wear tight-fitting garments for human figure measurement with few fastenings since the measurements were based on clothes design.

As for the posture during measurement, both upper limbs were raised to a height at which it was possible to judge by visual inspection that the angle of shoulder inclination had not changed (about 20°). Both wrists were placed on supports in order to maintain posture when standing still. The lower limbs were opened about 10cm parallel to make the inner surface shape of the femoral region easier to measure. The subjects were 55 women in their 60s and 70s, selected at random.

3-3. Measurement loci

After measuring the whole body using the 3-D measuring instruments, data were extracted from the loci of Back Neck Point (BNP), Front Neck Point (FNP), Side Neck Point (SNP), Shoulder Point (SP), Front and Back Arm Point (FAP, BAP), representing important points of clothes support in terms of clothes design. The setting definitions of the targeted measurement points are shown in Table 1 and Fig. 1.

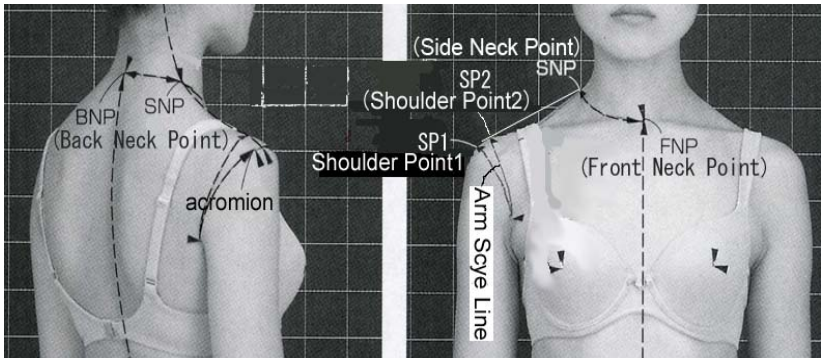

Fig. 1 Measurement point

measurement point	Abbreviation title	Definition
Back Neck Point	B.N.P	Point of processus spinosus of the seventh vertebrae cervicales
Front Neck Point	F.N.P	Intersection with center of line and sternum that connects sternum with edge of collarbone
Side Neck Point	S.N.P	Point located on shoulder ridge line in point that intersects with line where the former edge of trapezius "F.N.P" with "B.N.P"
Shoulder Point1	SP1	Intersection of shoulder ridge line and "Arm Scye Line"
Shoulder Point2	SP2	The lateral end in respect of shoulder ridge line and the tangent touched
Front Arm Point	F.A.P	Point on edge on fissura of front fossa axilla
Back Arm Point	B.A.P	Point on edge on fissura of back fossa axilla

Table 1 Definition of measurement point

The data measured consisted of the human figure silhouette, human figure horizontal cross section and horizontal cross-section overlay diagram, as well as the various measurement point coordinates, and so on. Meanwhile, to ascertain the body shape and morphological characteristics of elderly people, data from 43 adult women

students in their 20s were also used for comparison.

4. Shape analysis from 3-D measurement results

4-1. Shape of neck and shoulders in terms of coordinates

The coordinates obtained from 3-D measurement are shown in Fig. 2. To ascertain the relative positional relationships between coordinates of targeted measurement points, the various coordinates were converted on the basis of the FNP coordinates, and their average values were plotted on a 3-dimensional coordinate axis. Meanwhile, the 3-D measuring instruments used in this research were set to the coordinate axis shown in Fig.3. In this research, the right half of the body was measured.

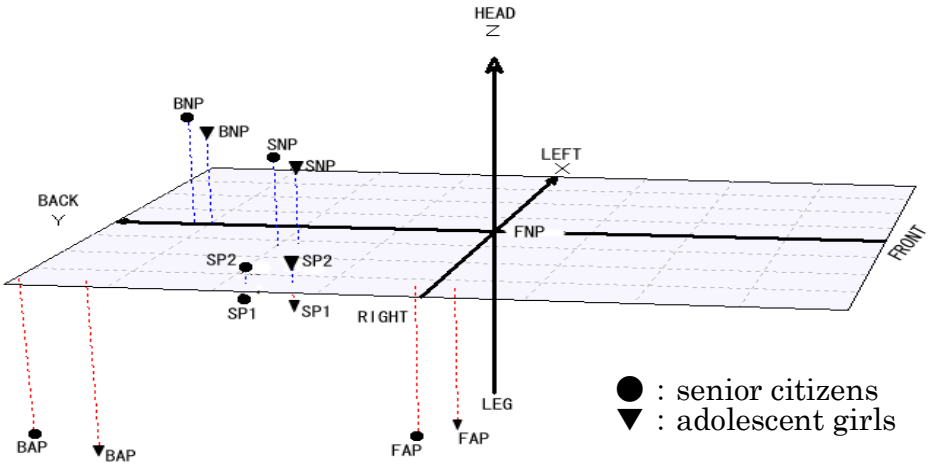

Fig. 2 Mean value plot of measurement point coordinates value

Comparing young people (▼) with elderly people (●), a significant difference in

positional relationship was seen in the measurement points of the neck and shoulders. In terms of the height relationship between BNP and FNP, in particular, the BNP position tends to be higher than the FNP position in elderly people (●) compared to young people (▼), revealing a significant difference between elderly and young people. While this has a big impact on differences in the neckline shape of clothes, as discussed below, it shows that the neckline height inclination when seen in profile is larger in elderly people.

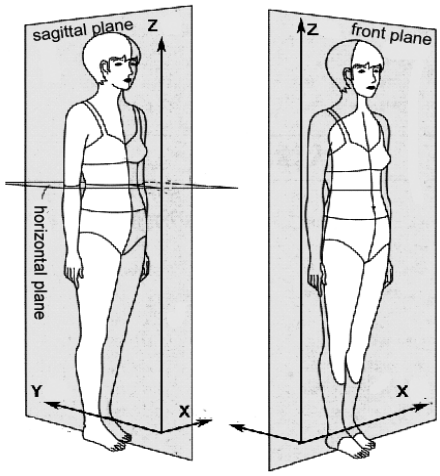

Fig. 3 Axis of coordinate of 3-dimensional measurement device

The results also show that the top of the shoulder and the arm scye are clearly positioned further back in elderly people. The position where the sleeve three-dimensional shape (upper limb three-dimensional shape) and torso three-dimensional shape intersect is related to the posture, physique, and other aspects of the human figure, and this has a major impact on locomotive functionality and aesthetic effect on clothes design. The top of the shoulder represents one

standard for this intersecting position, i.e. the sleeve attachment line as an intersecting line. The fact that there is a difference in the positional relationship of the aforementioned coordinates also highlights a difference in the angle of this intersection, as well as the arm scye angle, and the shape and curvature of the armhole of the clothes template, including the balance of chest width and back width. This suggests that incongruity will arise when using the same template in clothes design as for young people.

For all measurement points, the fact that a significant difference was seen between young people and elderly people in the height of each measurement point vis-à-vis the FNP position, i.e. Z coordinates, shows that there are differences in graphic balance in each locus of the clothes template. As a result, there will clearly be incongruity when using the same template design.

4-2. Shape of neck and shoulders seen from horizontal cross-section overlay diagram

Horizontal cross-section patterns featuring BNP, SNP, FNP, SP, FAP and BAP were laid over the XY coordinate plane, and the positional relationships between the various coordinates were measured. Fig. 4 shows the points of measurement and Table 2 the measurement results.

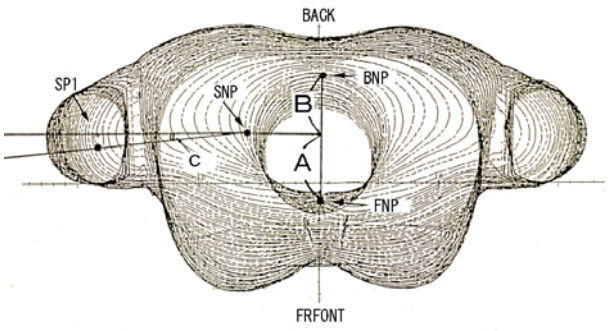

Fig. 4　Measurement part

Measurement part		Senior Citizens Average	Senior Citizens Standard deviation	Adolescent Girls Average	Adolescent Girls Standard deviation	
A㎜	FNP～SNP	62.958	9.989	57.488	7.911	**
B ㎜	SNP～BNP	38.696	11.972	39.347	6.633	
A/B	The ratio of A to B	1.766	0.539	1.516	0.387	**
C°( )	The level angle of A point and B point	7.038	6.022	9.779	5.387	*

Table 2　Measurement results

While the ratio between B and A in young people was about 1: 1.5, in elderly people it was about 1: 1.8, showing a significant difference in component ratios. In other words, the SNP that defines the ratio between A and B is set towards the BNP (towards the back) for elderly people. This has a big impact on the composition of the neckline in clothes design, shown in Fig. 5.

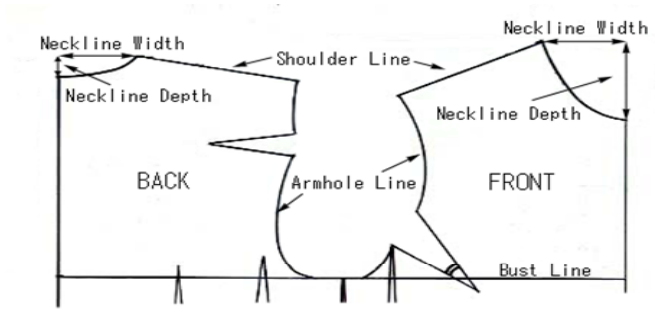

Fig. 5　Prototype pattern of clothes

In clothes design, patterns are made using a “template”, particularly in sites of education. The ratio between A and B defines the breadth and depth of neckline on this template. Currently, there is a boom in research on clothes for elderly people, and even apparel manufacturers are designing clothes aimed at elderly people. When this is applied to pattern making, however, the focus is mainly on one-dimensional corrections to body width dimensions according to the degree of fatness or thinness, adjustments to front-back height direction accompanying the curvature of the back, design proposals taking account of the ease or difficulty of dressing or undressing, and so on. There have been few attempts to grasp the shape and graphic balance of the various template parts that form the basis for design, such as correcting the balance between neckline breadth and depth. Since the A/B ratio of elderly people is larger than that of young people, if we assume the neckline to be a circle, it is clear that the SNP position that divides the neckline into front and back tends to be set further back than that for young people. Therefore, a problem with clothes for elderly people is that, when they wear clothes made with a neckline breadth and depth balance designed for young people, the front neckline depth is inadequate, and the clothes tend to ride up backwards to compensate for this. This is thought to explain the results of the wearing comfort survey included in the “Guideline for designing of clothes in consideration of elderly people –Apparel–” mentioned above, i.e. “Reasons for feeling dissatisfied: Places that do not fit my figure – Collar 14.9%, Feels too tight or constricted – 23%”.

A significant difference is also seen in “angle C”, which indicates the positional relationship between SNP and SP. A trend was seen for this angle to be smaller for elderly people than for young people. Fig. 6 shows a horizontal cross-section overlay diagram from the subject’s neck to the top of the shoulder in which the values of measurement items “A/B” and “angle C” most closely resembled the respective age group average for elderly people and young people. The outermost points on the X coordinate axis of this horizontal cross-section overlay diagram are, as shown in Fig. 7, the coordinate points that form a frontal silhouette of the human figure from the neck to the shoulders and top of upper limbs (frontal projection). This line form shows the characteristics of shoulder shape. The posture of “pushing the neck forwards, bending the back and pulling the arms and elbows backwards” is often used as a characteristic posture to express the body shape of elderly people. However, the fact that angle C is smaller than that of young people is thought to be because the arms are pulled backwards and SP is set further to the back, with the result that angle C becomes smaller. Furthermore, comparing with Fig. 6, the curvature of the silhouette composition line of young people from the neck to the top of the shoulder depicts a bold curve backwards from the neck, but conversely has a strong forward curvature towards the top of the shoulder. In contrast, this curvature tends to be rather more gentle from the neck to the top of the shoulder in elderly people compared to young people. This shows that the curve of the back, a major characteristic of the body shape of elderly people, occurs over a broad area from the neck to the top of the shoulder,

and the upper limb tends to be pulled backwards at the top of the shoulder. Young people have a more dramatic rise of the neck than elderly people (upright neck). The way in which the trapezius muscle stretches towards the rear neck is also prominently apparent on the cross-section overlay diagram. It is clearly the front edge of the backward-stretching trapezius muscle that forms the frontal silhouette of the human figure (frontal projection) of young people. Furthermore, judging by the characteristic “forward shoulder figure” of young Japanese people in recent years, whereby the top of the shoulder protrudes forwards – in other words, a body shape in which the point of intersection between the sleeve three-dimensional shape (upper limb three-dimensional shape) and the torso three-dimensional shape is further forward – the curvature tends to be stronger than in elderly people. This difference in the shape of shoulders is not something that can be addressed simply by one-dimensional correction of sizes when it comes to clothes design. The clothes template in Fig. 5 shows that we need to change the angle of inclination of the shoulder line, as well as the angle of the arm hole and other aspects of the shape itself, compared to those for young people.

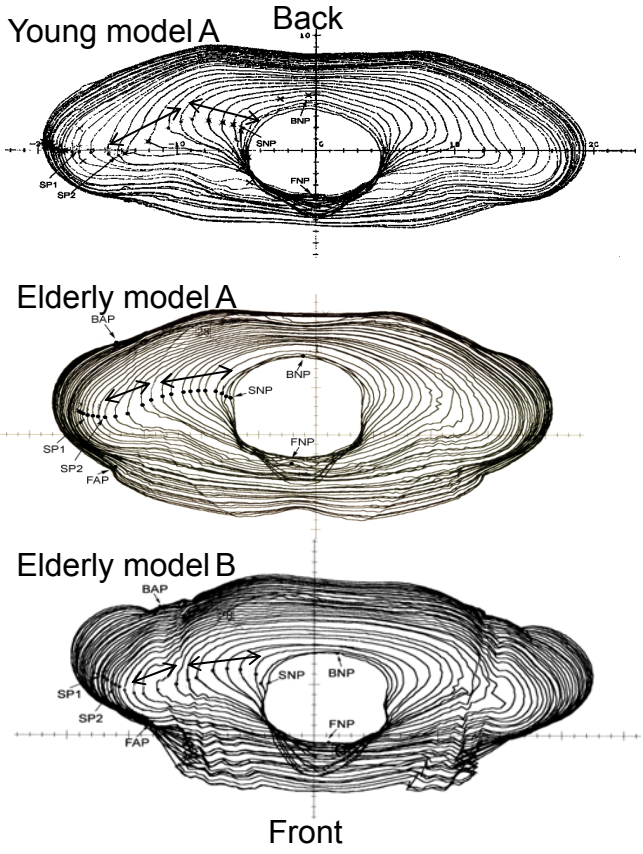

Fig. 6 Comparison of silhouettes from cervix part to shoulder

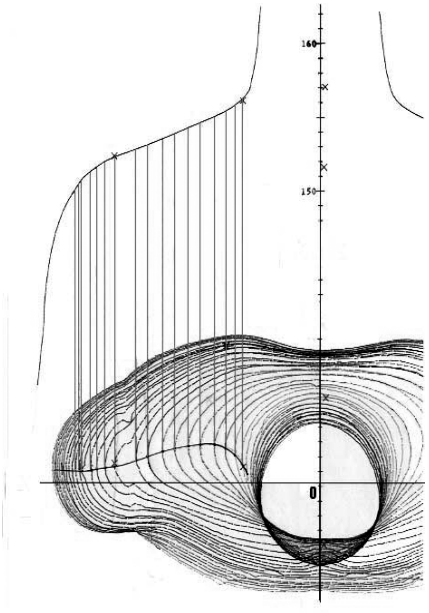

Fig. 7 Relation between human body front silhouette chart and section polymerization

chart

5. Conclusion

An important element in designing better fitting clothes is to ascertain the shape of the human figure. In previous research on human figure measurement points related to the compatibility of clothes, the author has attempted to facilitate human figure measurement using 3-D measuring instruments, as well as automatic setting of measurement points, targeting young people. The author has test fabricated simulation software, and has verified its theoretical soundness. As part of this, the shoulders and neck are complex loci of the human figure, in which changes in the curvature distribution of the human figure silhouette are pronounced and differences in physique between individuals are very large. This is because these loci are defined by skeletal features such as clavicula and shoulder blade and arm bone and formed from many surfaces with multiple curvature, while their external shape is formed from muscles such as the trapezius muscle and musculus latissimus dorsi. As such, measurement points are very difficult to set for these parts of the human body. Therefore, when the difference between individual physiques is relatively small, as in the case of young people, patterns can be matched to many models using an algorithm in which spin images of standard human figure landmarks are more or less constant, with the exception of specific physiques and those outside a given range of tolerance. By contrast, elderly people go through pronounced changes in physique

with age, and new theoretical parameters are therefore considered necessary for them. Partly because of this, it is essential that we carry out graphic analysis of this human figure shape that consists of such a wide variety of multiple curved surfaces (particularly in the shoulders and neck), and to identify their characteristics, rather than merely ascertaining one-dimensional length and size data in order to design better fitting clothes.

Today, ready-made clothes with abundant variation in design, color, pattern, materials and other elements are available on the market. In this climate, designing clothes that take account of the deterioration of physical and physiological functions, as well as providing clothes that satisfy the tastes of elderly people and take fashion sense into account is expected to form the basis of a spiritually affluent lifestyle for elderly people who are healthy in both body and mind. At the same time, this is expected to help stimulate economic activity in the apparel industry.

References:

Japanese Industrial Standard Committee (2002), *Guideline for designing of clothes in consideration of elderly people* (Tokyo: Japanese Standards Association)

Yanagida, Y (2006), *Measuring Point Setting on Three Dimensional Human Body Shapes for Clothing Design –Automatic Setting of Side Neck Point and Shoulder Point*, pp.1-10 (Tokyo: Journal of Japan Society of Kansei Engineering)

Cabinet Office (2008), *White Paper on the Aging Society* (Tokyo: Gyosei Co. Ltd.)

Miyoshi, M & Isozaki, A (1992), *The Improvement and the Test of Accuracy on the Noncontact 3-Dimensional Human Body Measuring System,* pp.1-17 (Tokyo: Bunka Women's University Research Bulletin)

Miyoshi, M & Kim, G (1999), *A Measurement of Horizontal Section Figures of a Human Body by a Three-dimensional Human Body Measurement System –Examination of Twist Correction and Averaging Section Figures*, pp.61-69 (Osaka: Journal of the Japan Research Association for Textile End-Uses)

Miyoshi, M & Hirokawa, T (2001), *Research on a Method of Measuring Void Volumes When Wearing a Jacket for Clothes Pattern Design - Using 3-D Measuring Instruments*, pp. 37-46 (Osaka: Journal of the Japan Research Association for Textile End-Uses)

Miyoshi, M (2002), *Chapter of Bunka Women's University Course Theory* (Tokyo: Textbook publication part)